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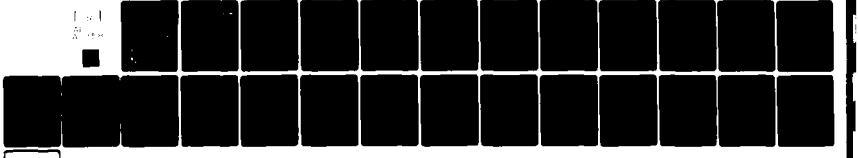

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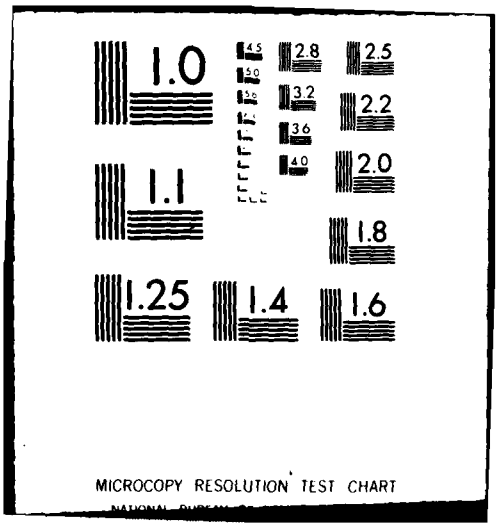
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BY THE U.S. GENERAL ACCOUNTING OFFICE

Report To The Secretary Of Agriculture

Better Collection And Maintenance Procedures Needed To Help Protect Agriculture's Germplasm Resources

The Department of Agriculture is responsible for preserving the base stock of domestic and wild food plants. This stock contains the genetic material, germplasm, necessary for U.S. crop development. Yet, a number of serious problems in collecting and in maintaining germplasm seriously endanger this Nation's germplasm resources.

GAO recommends ways for the Secretary to address these operational problems.

CED-82-7
DECEMBER 4, 1981

UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

COMMUNITY AND ECONOMIC
DEVELOPMENT DIVISION

B-205547

The Honorable John R. Block
The Secretary of Agriculture

Dear Mr. Secretary:

We reviewed the Department's management of plant germplasm to determine if the germplasm system adequately protected against catastrophic loss. We believe that there are actions which should be taken to improve the collection, storage, and maintenance of plant germplasm.

We discussed this report with representatives of the Director of Science and Education, the Agricultural Research Service, and the Cooperative State Research Service. We considered their comments in the report's preparation.

This report contains recommendations to you on pages 19 and 20. As you know, section 236 of the Legislative Reorganization Act of 1970 requires the head of a Federal agency to submit a written statement on actions taken on our recommendations to the Senate Committee on Governmental Affairs and the House Committee on Government Operations not later than 60 days after the date of the report and to the House and Senate Committees on Appropriations with the agency's first request for appropriations made more than 60 days after the date of the report.

We are sending copies of this report to the above committees; other interested committees and Members of Congress; and the Director, Office of Management and Budget. Copies are also being sent to your Inspector General, the Director of Science and Education, the Agricultural Research Service, and the Cooperative State Research Service.

Sincerely yours,

Henry Eschwege

Henry Eschwege
Director

GENERAL ACCOUNTING OFFICE
REPORT TO THE SECRETARY
OF AGRICULTURE

BETTER COLLECTION AND MAINTENANCE PROCEDURES NEEDED TO HELP PROTECT AGRICULTURE'S GERMPLASM RESOURCES

D I G E S T

All primary crops grown in the United States have been selectively developed from stock--or germplasm--native to other countries. Over the years, the genetic base of this Nation's crops has become increasingly narrow.

This narrow genetic base presents a potential danger to U.S. crop production. If genetically uniform characteristics in plants are suddenly adversely affected by disease, insects, or poor weather, the potential crop losses could be substantial. A 1972 National Academy of Sciences study characterized American crops as highly vulnerable to loss due to genetic uniformity.

To help protect against such loss, the Department of Agriculture established the National Plant Germplasm System to help preserve the base stock of domestic and wild food plants as a basis for breeding high crop yields and developing resistance to disease, insects, and poor weather. This is a cooperative system involving the Department, State experiment stations, and private germplasm preservers.

The system has numerous components, including the National Plant Germplasm Committee, the National Seed Storage Laboratory, plant introduction stations, crop advisory committees, and numerous independent curators. The plant introduction stations and independent curators store working collections to meet the day-to-day needs of plant breeders and researchers. The National Seed Storage Laboratory is intended to provide backup storage for the types of germplasm included in the working collections, ensuring against germplasm loss as a result of a disaster; for example, a fire or a tornado. (See ch. 1.)

GAO reviewed the Department's storage, collection, and maintenance procedures to determine if the germplasm system did protect against catastrophic loss.

CED-82-7

DECEMBER 4, 1981

PROBLEMS WITH GERMPLASM COLLECTION, MAINTENANCE, AND STORAGE PROCEDURES

GAO found that the system had numerous operational problems, primarily because of a lack of departmental attention and a low priority given to improving the system. Germplasm has become a high priority item in the Department's fiscal year 1982 budget, but whether sufficient funds will be provided to correct these problems remains to be seen. GAO identified the following as attributing to the Department's collection, maintenance, and storage problems.

--Insufficient information on who all of the germplasm curators are and what germplasm exists in storage or in its native environment. (See pp. 7 and 8.)

--Insufficient planning to determine what genetic material for crops important to U.S. agriculture should be collected and stored. (See p. 9.)

--Although the National Seed Storage Laboratory was established to provide permanent backup storage for the germplasm system, the curators GAO contacted had sent samples of only about 51 percent of the germplasm they held to the laboratory. These curators had higher priority uses for the germplasm or, in some cases, were unaware of the laboratory's function. (See p. 10.)

--Although germplasm storage at the National Seed Storage Laboratory seemed to comply with generally accepted storage conditions, most of the storage conditions for the working collections were inadequate. Of the 308,000 varieties of germplasm GAO identified as being stored in the United States, 193,000 (63 percent) stored as working collections were in inadequate containers. About 85,000 (28 percent) of these varieties also were stored in an undesirable climate. A loss of germplasm viability (ability to reproduce) could result among improperly stored seeds. (See p. 12.)

--When GAO took a random sample of 457 varieties of the six small grains (wheat, oats, barley, rye, triticales, and aegilops) stored at Beltsville, Maryland, it found that 6 percent

were missing and 9 percent were in short supply. (See pp. 11 and 12.) The germination rates of the seeds sampled were good, but 22 percent were more than 10 years old and nearing a point in time when viability could decline rapidly. (See pp. 14 and 15.)

--The small grains curator and some of the other working collection curators do not have testing equipment to identify when a sudden loss of viability occurs so that germplasm can be replenished. (See p. 15.)

--Some curators are behind in replenishing germplasm that is in danger of losing its viability. (See pp. 15 and 16.)

CONCLUSIONS

Insufficient management attention by the Department to germplasm collection, storage, and maintenance has endangered germplasm preservation within the United States. Although there has been increased emphasis in the Department's germplasm management during the past year, serious deficiencies within the system still must be overcome in order to have a viable germplasm resource.

RECOMMENDATIONS

In view of the priority the Department has given to the germplasm program, GAO recommends that the Secretary of Agriculture address the operational problems of the National Plant Germplasm System. (See pp. 19 and 20 for GAO's detailed recommendations.) These actions should include identifying all curators; implementing a policy for backup storage; determining the viability of the small grains collection; and assuring that germplasm is adequately stored, monitored, and replenished as needed.

AGENCY COMMENTS

The Department generally agreed with GAO's conclusions and recommendations. It stated that they were consistent with recommendations the Department's germplasm task force recently submitted, and that the recommendations would be used to help develop the fiscal year 1984 germplasm budget. (See p. 20.)

Contents

ABBREVIATIONS

ARS	Agricultural Research Service
GAO	General Accounting Office
GRIP	Germplasm Resources Information Project
LISA	Laboratory for Information Science in Agriculture
NPGC	National Plant Germplasm Committee
NPGS	National Plant Germplasm System
NSSL	National Seed Storage Laboratory
USDA	Department of Agriculture

CHAPTER 1

GENETIC DIVERSITY IS NEEDED FOR U.S. CROP DEVELOPMENT

All of the primary U.S. food crops have been developed from seed stocks--or germplasm--native to other countries. These crops have been domesticated from wild varieties which have been evolving for millions of years, resulting in a universe of domestic and wild plants. This universe of germplasm is the primary source for future crop improvement and one defense against threats, such as disease, insects, and poor weather, to crops. Plant germplasm is the source for inbreeding plants to produce higher yields and to resist crop threats. Although specific plant breeding techniques have developed improved crop lines superior to previous domestic and wild plants, the number of plant varieties planted in the United States and elsewhere in the world has been vastly reduced. This dependence on a more limited number of crops has made the continued protection and maintenance of genetic diversity 1/ critically important if an ample variety of domestic and wild plants is to be available for inbreeding.

A lack of genetic diversity--genetic vulnerability--has been responsible for several agricultural catastrophes having disastrous impacts. In the 18th century, a food plant from the Andes Mountains of South America, the potato, was introduced into Ireland. The genetic diversity of the potato that was introduced was limited, but, isolated from some of its diseases, the potato yielded well and became the major food crop in Ireland. In the 1830's, with the Irish population at 8 million, a previously unknown disease appeared in Ireland's potato crop. Within 10 years, 2 million Irish emigrated, 2 million died, and 4 million remained, many in abject poverty. The Irish had inadvertently narrowed the genetic base of their potato crop, resulting in little or no resistance to the fungus which wiped out major portions of the potato crop.

PRESERVING GENETIC DIVERSITY IN U.S. AGRICULTURE IS IMPORTANT

While the United States has not experienced a genetically based crop failure the magnitude of Ireland's potato failure, crop failures have occurred. In 1953 and 1954, a wheat disease, wheat stem rust, took 65 and 75 percent, respectively, of the pasta crop. The disease also took 25 percent of the bread wheat in 1954. The 1970 southern corn blight destroyed approximately 20 percent of the U.S. corn crop. The effect of these failures was higher

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1/Genetic diversity refers to the variety of domestic and wild crop plants which remain today and which represent the world's entire genetic resources.

food costs, but no human starvation. However, such a corn crop failure would have been disastrous in countries like Guatemala or Kenya where corn is half the daily calorie intake. Outbreaks of disease like the wheat stem rust or the southern corn blight are evidence of the need for genetic diversity and the liability of genetic uniformity, in that the small genetic bases in U.S. agriculture make us more susceptible to crop failures.

A 1972 National Academy of Sciences study "Genetic Vulnerability of Major Crops" indicated that nearly all of the U.S. basic food crops are on such a narrow genetic base as to be highly vulnerable to some new type of disease or insect or common environmental stress. For example:

--For hard red winter wheat, about 40 percent of the acreage is planted with just two varieties and their derivatives.

--For soybeans, the genetic base generally grown is limited to six seed varieties.

The narrow genetic base of U.S. crops has created a potentially unstable relationship between basic food plants and stress conditions such as disease. For example, genetic changes are constantly taking place in organisms causing individual diseases. If a disease suddenly infects a previously resistant plant, the disease will be able to spread across the entire genetically uniform plant population. In parts of the world where plants are genetically uniform only in small areas, a disease affecting a unique trait of a plant in one of those areas would have little effect on the crop beyond that area. However, in the United States where certain genetic traits often extend nationwide, a disease could have a significant effect.

Protection of agricultural output based on seeds with a narrow genetic base is largely dependent on genetic diversity, but the process for maintaining genetic diversity is changing. Historically, the United States has been able to return to areas of genetic diversity to collect germplasm for further breeding programs. However, in the last decade Mexican farmers have planted hybrid corn seed from a U.S. seed firm; Tibetan farmers have planted barley from a Scandinavian plant breeding station; and Turkish farmers have planted wheat from the Mexican wheat program. Each of these areas of crop-specific genetic diversity is rapidly becoming an area of seed uniformity, resulting in loss of genetic diversity.

The reason for concern within the agricultural community about the loss of native strains is the irreplaceable nature of genetic diversity. The only place genes can be stored is in living systems such as the embryo in a kernel of corn or wheat. The native varieties can become extinct once they are replaced in favor of seed introduced through plant breeding. The genetic heritage of a thousand years in a particular area can be lost in a single year.

A time may come when man is totally dependent on the genetic strains he has preserved. The genetic material in a seed is a natural resource. Unfortunately, enormous stores of genetic diversity worldwide are being lost at a continually increasing rate. In Taiwan, where importance of preserving germplasm was not recognized, the number of varieties of rice fell from about 1,000 in 1959 to 8 or 10 within a 10-year period. Specific crop varieties are grown to produce a better food crop, increase yields, and raise farm income.

Serious erosion of the genetic natural resource has occurred through many factors of civilization. In addition to breeding manipulations, these include

--increased grazing,

--abandonment of old farming systems, and

--development accompanying population growth.

In the future it may become difficult, if not impossible, to find needed genetic strains anywhere in the world. Thus, whatever genetic support for U.S. agriculture that now exists in native food production systems may not always continue to exist unless steps are taken to store seed stocks and preserve their genetic diversity for future use.

DEPARTMENT OF AGRICULTURE INVOLVEMENT IN MAINTAINING GENETIC DIVERSITY

The United States has long recognized the need to preserve genetic diversity of food crops. American consuls were instructed in the early 1800's to collect seeds and return them to the United States. This function was the responsibility of the U.S. Patent Commissioner from 1836 until the Department of Agriculture (USDA) was established in 1862. In 1898, USDA established the Office of Seed and Plant Introduction to collect, catalog, and distribute seed. The Research and Marketing Act of 1946 established regional and interregional plant introduction stations to preserve and distribute seed. These stations are run cooperatively by Federal and State governments and augment USDA's National Seed Storage Laboratory (NSSL), established in 1958 to preserve and conserve seed stocks on a permanent basis.

USDA's objectives are relatively straightforward: collect, maintain, evaluate, and distribute plant germplasm to users. These functions are the responsibility of USDA's Agricultural Research Service (ARS). ARS' responsibilities include:

--Collecting plant materials, or obtaining them through exchange or contribution, from both U.S. and foreign sources. Germplasm enters the U.S. system by going directly to one of the regional stations or, in the

case of foreign material, going to USDA's Principal Plant Introduction Officer for subsequent distribution.

--Maintaining germplasm to assure that the plant stock stays alive. This is normally achieved by cold storage of the seed and periodic growth of the seed (called grow-out) for replenishment.

--Evaluating genetic resources for morphological (physical characteristics) and genetic traits so that plant breeders can easily identify plant characteristics.

--Distributing germplasm so that new genetic material can be introduced in breeding programs.

These objectives are carried out by numerous operating components representing Federal, State, and private sectors which make up the National Plant Germplasm System (NPGS). These components receive advice from the National Plant Germplasm Committee and various crop advisory committees.

It is important to note that NPGS is not a federally managed or controlled system, but a State/Federal cooperative system. While all of the germplasm curators within the system come under some Federal oversight, about 20 private curators, including major collections such as cotton and soybeans, are only loosely associated with NPGS. USDA funds or assists in funding some of these collections but exercises no management control.

Our prior review of NPGS

In April 1981 we issued a report 1/ which discussed USDA management of NPGS. We concluded that weaknesses in NPGS' management contributed to genetic vulnerability within the United States. We recommended that USDA centralize control over the system and develop a long-range plan for managing plant genetic resources.

USDA's response to our earlier report has been largely favorable. While disagreeing with our recommendation for centralized management, USDA has provided more attention to germplasm management by raising the reporting level of the germplasm coordinator. Additionally, a task force has been established to prepare a long-range plan for plant genetic resources. In mid-October 1981, this task force submitted recommendations for improving the germplasm system to the Director of Science and Education, USDA.

1/"The Department of Agriculture Can Minimize the Risk of Potential Crop Failures," (CED-81-75, Apr. 10, 1981).

OBJECTIVES, SCOPE, AND METHODOLOGY

Our earlier report also identified operating problems with the germplasm system. These problems were not fully addressed in the report but were believed to be of critical importance in maintaining the viability (ability to reproduce) of U.S. germplasm collections. Subsequently, we initiated this review to address these issues and to recommend corrective actions.

Our work concentrated on agencies and individuals currently involved with germplasm collection and maintenance. We contacted the National Seed Storage Laboratory; the four plant introduction stations; the Beltsville Agricultural Research Center in Beltsville, Maryland; and about 30 germplasm curators throughout the United States. We also visited USDA headquarters in Washington, D.C. These agencies and individuals were contacted personally and/or by telephone and correspondence.

In addition, we evaluated USDA procedures for collecting new germplasm. We visited personnel at the Beltsville Agricultural Research Center and reviewed their records to determine procedures for collections and volume of collections. Two representatives of private seed companies and two researchers also were contacted to determine the extent of their collection activities.

We used a questionnaire to gather part of our information. Our objective was to gather information to (1) evaluate curators' storage facilities, (2) identify the quantity of germplasm they had in storage, (3) determine the status of their programs to replenish germplasm and preserve viability, (4) identify whether they provide germplasm to NSSL for storage, (5) note any germplasm they have ceased to maintain, and (6) determine how germplasm was distributed to other users. The initial universe for our questionnaire was a list of 48 contacts USDA identified. However, USDA officials told us that neither they nor anyone else is aware of all the curators in the United States. We eliminated 18 contacts from the list because they did not preserve germplasm. We received questionnaires from 29 of the remaining 30 curators.

We conducted tests on samples of germplasm to determine their viability. For the small grains collection stored in Beltsville, we requested a random sample of 457 accessions (varieties of seeds) to test their viability and to evaluate the condition of seeds in storage. However, as discussed on page 15, we received samples of only 357 accessions for testing. The testing was done with the cooperation and under the supervision of the Director of NSSL. We conducted germination tests on the samples in the NSSL laboratory, and private and public agricultural experts helped us evaluate the results.

We reviewed the status of the Germplasm Resources Information Project to develop a germplasm information system. We visited the contractor, Laboratory for Information Science in Agriculture, responsible for developing and implementing the system and compared

its progress with contract requirements and goals. This included measuring the meeting of time milestones and reviewing budgeted and actual expenditures.

We also used the questionnaire to review the status of the curators' programs to replenish germplasm for preserving viability. In addition, we contacted 11 public and private curators who represent a geographic cross section of U.S. curators to obtain information on the status of their replenishment needs. The information obtained from these 11 curators included whether or not they were behind in their replenishment program, and, for those behind, the reasons for being behind, the crops and number of accessions that need replenishment, and the costs estimated to meet those needs.

We met frequently with USDA's germplasm task force and exchanged information with them on our mutual efforts.

CHAPTER 2

INADEQUATE COLLECTION, MAINTENANCE, AND STORAGE OF GERMPLASM COULD LEAD TO REDUCED GENETIC DIVERSITY

As indicated in chapter 1, the United States has no native sources of germplasm for major crops and depends on germplasm collections to maintain a supply of germplasm. To better assure genetic diversity and to provide a source of germplasm for crop improvement, it is essential that available germplasm is collected and, once collected, that it is properly stored. Both of these conditions must be met to assure a viable collection. Without a complete collection, germplasm which may be necessary for plant breeding is just not available. Without proper storage and maintenance, the viability of the stored germplasm will diminish and eventually be lost.

Serious problems plague the collection, maintenance, and storage of germplasm. USDA does not know the universe of germplasm stored in the United States and has no systematic plan for collecting germplasm. Germplasm storage is characterized by inadequate storage facilities, missing germplasm, failure to replenish germplasm or follow backup procedures, and failure to monitor the viability of the collection.

The Administrator and program officials within ARS cite lack of funds and staff as the source of their problems. Until recently, germplasm has had a relatively low priority within USDA and thus has not received adequate management attention. ARS has now made germplasm a high priority.

UNIVERSE OF GERMPLASM IS UNKNOWN

Loss of native germplasm endangers the preservation of genetic diversity. As noted in chapter 1, farmers throughout the world are replacing native germplasm in their fields with uniform germplasm and many natural habitats are endangered by increasing population spread. It is assumed by plant geneticists that much valuable germplasm has already been lost, but no one knows how much. Once native germplasm becomes extinct or inaccessible, the genetic diversity of the germplasm is lost or unavailable. Without knowing what germplasm is available and what has been collected, meaningful planning for collection is difficult and subject to omissions.

A centralized inventory which could be used to plan collections as a basis for preserving germplasm is unavailable. Although it is generally known where seeds for food crops originated, there is no inventory that indicates where germplasm is preserved in storage in the United States or in other parts of the world because no one had undertaken a project to combine available information

and identify germplasm not in an inventory. USDA currently has a project (the Germplasm Resources Information Project (GRIP)) to develop an information system for germplasm stored in the United States. The system's purpose is to (1) make genetic resources data available to plant breeders and researchers, (2) provide an efficient communications link between public and private sources in NPGS, and (3) provide a uniform system to curators for collecting and maintaining the data and transferring this data in a timely and accurate manner to other curators and germplasm users.

GRIP's major goal is to provide service to the National Plant Germplasm System. For example, GRIP will obtain, catalog, describe, and provide plant germplasm information to various scientific users in the United States and abroad. For GRIP to properly serve NPGS, it must provide information to assist in decisionmaking. Basically, this will include information on collection, preservation, and accessibility of plant germplasm as well as characteristic traits such as height and disease resistance. However, as noted on page 5, not all germplasm curators are known.

To develop the germplasm information system, USDA initiated a feasibility study under a cooperative agreement with the University of Colorado to investigate the planning and development of a nationwide program to assemble, analyze, and retrieve information on crop germplasm. The system's objective is to make germplasm data more accessible to users.

The feasibility study was completed and a general plan was approved by USDA in 1977. The general plan called for a 5-year development and implementation schedule with a total cost of $5 million. Actual work on the information system began in October 1977.

In 1978 the project and its principal managers and technicians transferred to Colorado State University, Fort Collins, where work on the project continues. The university entity is called the Laboratory for Information Science in Agriculture (LISA). This information system is expected to interface with an international system for worldwide dissemination of germplasm data.

To date, development of the information system is moving along according to plan. The ARS Administrator is generally satisfied with LISA's development approach for the project and its expertise. According to both USDA and LISA, an operating, online information system will be in place by late 1982 or early 1983. This time frame is in accordance with the feasibility study's schedule.

There is also a current effort to develop a worldwide inventory of germplasm. The International Board of Plant Germplasm Resources is in the process of instituting a project to inventory the world's germplasm. This project was to begin in 1981 and should be completed by 1984.

THE UNITED STATES NEEDS A BETTER PLAN FOR COLLECTING GERMPLASM

Collecting native germplasm is a key element in preserving genetic diversity. Currently, the United States has a twofold system for collecting germplasm: expeditions and exchanges. (See following discussion.) Expeditions account for 20 percent of the annual collections, and exchanges 80 percent. The exchanges are done through the mail. USDA is involved in both expeditions and exchanges. The user community gets its germplasm through exchanges, NSSL, or plant introduction stations.

Expeditions

USDA has a formal procedure for processing proposals for expeditions to collect germplasm. Researchers submit proposals to one of the four plant introduction stations for review and ranking. If the expeditions are approved, they are ranked according to the professional judgment of the regional representatives. Proposals from all four regions are then submitted to USDA headquarters for a second review. These proposals are ranked at headquarters according to, again, the professional judgment of headquarters representatives. Neither the regional nor headquarters representatives have any criteria other than their professional judgment to set procedures for collecting expedition proposals.

Anticipating a large volume of requests and a need to make decisions on such requests, USDA established expedition procedures. These procedures appear somewhat meaningless, however, because all reasonable proposed expeditions are eventually approved and funded. Most proposals--between six and seven per year--are funded in the year requested from an annual budget of $34,000.

Exchanges

Requests for germplasm can be made through USDA's Beltsville Agricultural Research Center. Requests are received and inventories are reviewed to identify available sources. A request is then sent to the source which in turn sends the germplasm to Beltsville. USDA then sends the germplasm to the requestor. In addition, requestors, such as researchers and breeders, can bypass USDA and go directly to a source.

The requests are usually initiated by the user community to meet their own needs. The Principal Plant Introduction Officer told us that USDA does not normally initiate any exchanges itself because it does not have an organizational unit to address such needs and no funds are available to establish such a unit.

In addition, USDA does not record all germplasm that is received. The Principal Plant Introduction Officer recognizes that USDA should keep records of all germplasm received, but

stated that it cannot keep up with the volume because it does not have sufficient staff. In 1979 about 5,500 out of about 34,000 items received were added to USDA's inventory.

GERMPLASM STORAGE AND MAINTENANCE PROCEDURES NEED IMPROVEMENT

Collecting germplasm is only the initial step in preserving genetic diversity. Once germplasm is collected, it must be adequately stored and periodically monitored and replenished. However, both storage procedures and facilities have been inadequate. Also, shortcomings exist in monitoring and replenishing stored germplasm. As a result, some germplasm has been lost and the viability of some of the remaining germplasm is questionable.

Adequacy of storage

The U.S. system provides for primary (short-term) and backup (long-term) storage. USDA's NSSL provides backup storage for all germplasm, while other curators, who treat their germplasm collections as "working" collections, 1/ provide short-term storage. USDA initiated the concept of backup storage to guard against germplasm loss due to catastrophes such as tornados and floods and hazards such as fire and breakdowns of refrigeration equipment.

Gaps in backup storage

NSSL was established in 1958 to provide backup germplasm storage as a base collection for the United States. Accordingly, the loss of germplasm and genetic diversity in one unexpected disaster would be prevented by having the germplasm stored in two locations.

The backup storage program has not been adequately implemented. The Director, NSSL, told us that NSSL did not have duplicate germplasm from all other curators, mainly because NSSL was unaware of much of the germplasm being stored in the United States. In addition:

--NSSL has about 113,000 types of seeds in storage, and about 80,000 seeds from the small grains collection that NSSL told us had not been containerized and integrated into its inventory because of staff shortages.

--We contacted 29 curators throughout the United States who have approximately 252,000 types of seeds (including the 80,000 from the small grains collection), and they told us that only 129,000 types have been sent to NSSL.

1/A collection of germplasm from which seeds are distributed to researchers and breeders.

Although established by USDA to provide backup storage, NSSL does not have the authority to require that germplasm be sent to it for backup storage. Curators we contacted told us that they do not routinely provide germplasm to NSSL because such action was not their first priority, or they were not aware of NSSL's mission. They said that they will provide samples to researchers and/or seed breeders before they send samples to NSSL. Therefore, some short-term curators are the only preservers of certain varieties of germplasm. Also, USDA does not have authority over all short-term curators because some are outside USDA's organizational framework.

The ARS Administrator said that he was unaware that the backup policy had been inadequately implemented and agreed that it should be implemented.

Missing germplasm from small grains collection

The amount of germplasm in the small grains collection was unknown. Also, some of the seed that was listed in the inventory was not in storage.

We selected a sample of 457 accessions drawn randomly from the small grains collection. This sample was stratified over the six types of grain in the collection and was designed to provide results at the 95-percent confidence level (±8 percent). We estimated, based on this sample, that about 15 percent of the total (82,295) accessions were unavailable either because no seed was available for distribution (6 percent) or the seed was in short supply (9 percent). (See table on p. 12.) According to the collection curator, the missing seeds were a result of either mistaken inventory numbers or, after being assigned inventory numbers, discovering that the seeds were either dead or not of sufficient quantity to maintain. Of the seeds in short supply, two-thirds were being regrown for replenishment, but the curator of the small grains collection told us that he was unaware that the remaining one-third were in short supply. Seeds to be grown out for replenishment because of short supply were determined by annual physical reviews of the collection. According to the curator of the small grains collection, these reviews have been limited to part of the collection because of insufficient funds to grow out all seeds in short supply.

Accessions Missing or in Short Supply at the Small Grains Facility

(Estimate based on stratified random samples)

Crop	Total accessions	Total missing		Total in short supply		Total missing and in short supply	
		Number	Percent	Number	Percent	Number	Percent
Wheat	36,788	400	1.09	3,999	10.87	4,399	11.96
Barley	25,376	723	3.09	2,169	9.28	2,892	12.37
Oats	19,457	3,421	17.58	1,069	5.50	4,490	23.08
Rye	1,379	161	11.67	161	11.68	322	23.35
Triticale	914	118	12.91	295	32.28	413	45.19
Aegilops	381	48	12.59	8	2.10	56	14.70
Total	82,295	4,871	5.92	7,701	9.36	12,572	15.28

The ARS Administrator agreed that the small grains collection needed to be re-inventoried.

Adequacy of storage sites

No universally accepted standards exist for determining what is adequate storage for germplasm, but USDA geneticists and botanists involved in germplasm storage generally agree that the following are necessary to maintain seed viability.

--The factors most important in maintaining viability are temperature, relative humidity of the storage room, type of packaging for storage, and seed moisture content.

--Moisture content of the seed is the most important factor and is dependent on the other three factors.

--Lowering temperature, humidity, and moisture content is known to extend seed life during storage.

--Moisture-resistant packaging is best for maintaining seed moisture content.

--A rule of thumb for short-term storage (1 to 5 years) is that the sum of temperature in Fahrenheit and relative humidity in the storage room should not exceed 100.

--For long-term storage, subfreezing temperatures should be maintained and seed should be stored in moisture-proof containers to prevent any fluctuation in seed moisture content.

Although some factors considered important in maintaining germplasm viability are met, the short-term curators we contacted generally did not comply with the majority of factors, primarily because they lacked the correct type of containers--again due to a lack of funds. As shown in the following table, some factors exist that may cause damage to germplasm. Only NSSL (with 113,000 types of seeds) and one short-term curator (with about 1,500 types of seeds) used storage containers adequate to protect against moisture.

Schedule of Storage Conditions Used by Curators

	Good containers		Poor containers					
	Adequate humidity and temperature control		Adequate humidity and temperature control		Adequate temperature control		Inadequate humidity and temperature control	
Universe of Germplasm	Number	Percent	Number	Percent	Number	Percent	Number	Percent
307,645	114,515	37.2	108,491	35.3	80,421	26.1	4,218	1.4

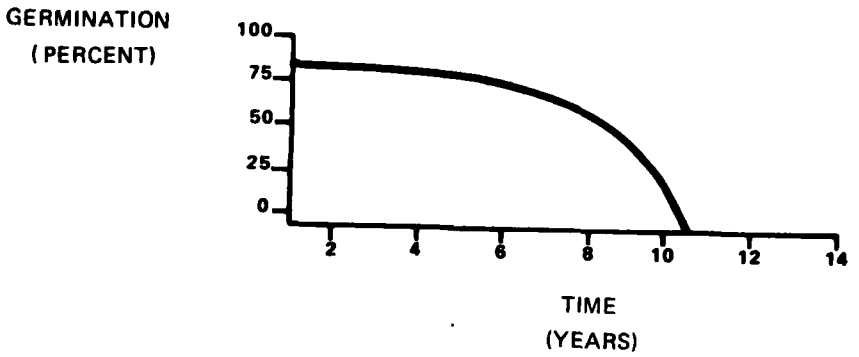
In addition, about 71 percent of the germplasm stored by short-term curators has been in storage longer than the 5-year criteria for such storage.

The adequacy of storage at short-term curators appears to be questionable regarding preservation of genetic characteristics. For practical purposes, all seed is stored in containers inadequate to keep moisture content down. If moisture content is the most critical factor in maintaining seed viability, over 99 percent of the seed at primary, short-term curators is vulnerable to moisture infiltration. Moisture control is a particular problem with short-term curators because constant access to the collections is needed. Sealed cans or containers offer protection against excess moisture, but constant opening and resealing of these containers is not practical because of the time and expense of resealing. Therefore, proper humidity control is important for these collections. In this light, we noted that almost 40 percent of the seed in short-term collections is stored without proper humidity control.

The ARS Administrator agreed that germplasm should be stored in adequate facilities and was unaware that storage conditions were as we noted.

Monitoring germplasm viability

Germination tests are a key element in maintaining genetic viability. Seed will typically maintain a relatively constant germination level 1/ over time, but then the rate will drop quickly, as illustrated in the following graph.



The time period before the germination rate begins to drop will vary according to seed type, although storage conditions will also have an effect. The time when the seeds' germination rate begins to drop rapidly can be identified by monitoring the germination rate, and the seed can be replenished by growing it out. Curators told us that periodic grow out of all crop seeds, in lieu of monitoring germplasm rates, is not efficient. For example, some seeds can be grown out only in certain climates; controls are needed to prevent cross pollination among separate varieties; and the labor needed to plant, monitor, and harvest seed growing out is expensive.

Short-term curators' ability to monitor germination is limited. Of the 29 curators who responded to our questionnaire, 8 did not do germination tests. The primary reasons they cited for not doing germination tests were lack of equipment and insufficient staff. Other reasons included an inadequate quantity of seeds to do tests and, in one instance, a belief that tests were unnecessary.

Geneticists and botanists involved in germplasm storage have expressed concern about the viability of seeds and the adequacy of storage conditions at the small grains collection stored in Beltsville, Maryland. Because of these concerns, USDA established in May 1979 the Task Group on the Assessment of the Small Grains Collection to review the situation at Beltsville. In a June 1979 report, the task force recommended that the small grains collection be moved to another storage site. As a result of this report, USDA made improvements in the storage facility including, among other changes, cooling, insulation, and elimination of windows.

To determine viability of the small grains collection at Beltsville, we requested a random sample of 457 accessions from

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1/The percent of seed that will grow (germinate) when planted.

the six collections of small grains at Beltsville; we then had germination tests done on the seeds. We were sent only 357 accessions from the six collections (see p. 11 for more information about missing seeds). The germination results on these seeds were generally high, and the consensus of opinion from experts was that the viability of the seeds tested was good. Over 67 percent had a germination rate of 90 percent or more, and only about 5 percent had a germination rate of less than 50 percent.

Although the viability of the seeds tested was good, there are no facilities to test the germination rate of the seeds. As explained on page 14, the germination rate of seed drops rapidly when it begins to decline. Without testing the germination rate, there is no way to monitor when the rate begins to decline. The curator at Beltsville sampled 1,000 of his seeds and found that 25 percent had not been replenished through grow-out for over 10 years. Of the seeds we sampled in the germination tests, 22 percent had not been replenished in over 10 years. The curator at Beltsville expressed concern that, generally, seeds in storage for 10 years or more are nearing the point in time when viability will decline rapidly. He also stated that he believes germination testing equipment is needed for the small grains collection and that he has been unable to get the requested funds from the regional director for the equipment since June 1980, when he became curator.

Information from our questionnaire revealed that 8 of 29 curators do not have germination testing equipment to monitor viability. The cost to a curator for monitoring equipment appears to be nominal. Curators we contacted who did not have germination testing equipment stated that they believed such equipment could be obtained for no more than $10,000 per curator. They also said that germination testing could be contracted out at a lesser initial cost.

The ARS Administrator agreed that germination testing equipment should be available for all curators to minimize the risks of seeds losing viability. ARS officials also were aware that many curators did not have germination testing equipment. The Administrator believed that such testing was necessary and would best be done at a centralized location such as NSSL or a State university seed testing laboratory.

Replenishment of germplasm

Once germplasm is in storage, its maintenance is not assured unless the germplasm is periodically replenished once its viability declines. Also, the primary curators supply seeds to researchers and breeders on request. This can lead to reduced inventories so that supplies must be replenished. The germplasm is maintained by periodically growing out replacement germplasm.

The situations regarding seed monitoring among curators vary. The majority of respondents to our questionnaire said that they only grow out germplasm as supplies drop below required minimums. Other respondents stated that they are behind in their growing out due to funding and staff shortages. In either case, the germplasm collection may lose its viability.

The status of replenishment programs varied among curators. To get information beyond that obtained from the questionnaire about grow-out conditions among curators, we contacted 11 curators, including NSSL, about the status of their programs. These curators were representative of major U.S. crop collections, located in different parts of the country, and represented both the public and private sector. NSSL and five other curators replied that they were behind in their replenishment programs and, therefore, were concerned about the viability of those seeds needing to be replenished. The table below gives the curators' estimates of the costs of catching up on their grow-out programs. We did not attempt to verify the accuracy of these estimates.

Site	Crops	Costs to catch up
Ames, Iowa Plant Introduction Station	Corn, tomatoes, alfalfa, and carrots	$103,000
Experiment, Georgia Plant Introduction Station	Sorghum, melons, tropical legumes, and peanuts	36,000
Beltsville Agricultural Research Center	Rice	70,000
Beltsville Agricultural Research Center	Wheat, barley, and rye	10,000
NSSL	Various	616,000
Texas A&M University	Cotton	12,000
Total		$847,000

Each of these curators cited shortages in funding and/or staff as the reasons for their falling behind in replenishment.

The ARS Administrator agreed that the curators' replenishment programs needed USDA attention.

GERMPLASM HAS NOT HAD SUFFICIENT MANAGEMENT ATTENTION

The germplasm community is aware of most of the problems identified in this chapter. Most would agree that their problems need corrective attention. Most cite a lack of funds and staff as reasons for these problems, but the solution is not that simple.

The germplasm community is highly divided. As indicated in our April 1981 report, the National Plant Germplasm System is not really a system. It is more of an amalgamation of various germplasm participants who have a number of common goals but no real means of achieving those goals. Until recently, the National Plant Germplasm Committee (NPGC), which represented the system, had no members controlling staff or funds. NPGC's decisions or proposals had no weight and were to a large extent ignored by USDA. Within USDA, germplasm has been a relatively low priority item, receiving minimal budget increases.

Under ARS, responsibilities for germplasm management are divided among four regional administrators, with limited oversight by ARS upper-level management. The various germplasm program units are managed independently without consistent goals and objectives necessary to meet the germplasm system's needs. The programs are monitored and coordinated, however, at the national level by the germplasm coordinator.

Fortunately, this situation is improving. Over the past year, USDA, in particular ARS, has made germplasm a higher priority, increasing management involvement and developing (in process) a long-range plan for plant germplasm. Germplasm was the subject of a special budget analysis for the 1982 fiscal year budget submission. Germplasm was the second-ranked item (in terms of priority for budget increases) in ARS' budget submission. For 1982, a $1.8 million increase is being sought for germplasm programs. The impact of the President's revised budget on this increase was uncertain as of mid-October 1981.

CONCLUSIONS

Insufficient management attention by USDA to germplasm collection, storage, and maintenance has endangered germplasm preservation within the United States. In the past, USDA has not dealt with problems within the collections. Although there has been increased emphasis in USDA germplasm management during the past year, serious deficiencies within the system, as noted below, must be overcome in order to have a viable germplasm resource.

--USDA has not adequately satisfied the roles of planner and coordinator in establishing procedures to meet germplasm preservation needs. Without adequate planning and a general knowledge of what the universe of

germplasm is in the United States, the U.S. system for collecting germplasm serves to provide individual research needs rather than overall germplasm preservation needs. Once U.S. and worldwide inventories are completed, USDA will have a good basis to better plan for collecting germplasm. However, substantial action could be taken on an interim basis to use existing information on available germplasm for establishing priorities and procedures for collecting germplasm. In our April 1981 report, we recommended that such action be made an integral part of long-range planning for plant germplasm management.

--USDA has serious gaps in primary and backup storage of germplasm which could lead to permanent loss of genetic stocks. The backup seed storage program was not working adequately. Seeds that were not in backup storage at NSSL were stored by curators, and seeds were stored at NSSL that were not stored at other known curators. As a result, some short-term curators were the sole preservers of germplasm. Duplicative storage of germplasm is essential "insurance" to protect against catastrophe in the event the primary stock is lost or depleted.

--The small grains collection has serious gaps due to missing or depleted stock. This collection is the primary germplasm source for the Nation's most economically important crops. Germplasm that was thought to be in storage and in reality was not in storage could affect many aspects of germplasm maintenance. For example, germplasm that needs to be collected would not be collected, germplasm thought to be available for research would not be available, and backup storage might not exist.

--Storage conditions at most of the short-term curators are not suitable to maintain genetic viability. Additionally, genetic viability at many collections is not monitored nor are seeds grown out at regular intervals, creating a situation whereby the usefulness of some collections might be very limited. Equipment to monitor germination rates is needed to preserve genetic diversity. Without this equipment, a curator cannot monitor germplasm viability. Regardless of how good the curator's storage facility controls temperature, humidity, and moisture, seed will eventually lose viability. If monitoring is not done, germplasm could be lost because the germination rate could unknowingly decline to the point where the germplasm loses its viability. The alternative to monitoring--frequent growing out--would be a more costly process than germination testing.

--Some of the germplasm collections could be lost unless the replenishment programs of some of the curators are

updated. USDA needs to determine more specific information from the curators we contacted, as well as other curators, to identify what actions are needed to address this problem.

Any one of the above situations could create a real potential for germplasm loss. Taken together, it is quite probable that significant amounts of germplasm have been or could be lost.

RECOMMENDATIONS

In view of the priority USDA has given to the germplasm program, we recommend that the Secretary of Agriculture, to ensure continued viability of U.S. germplasm collections, take the following specific actions:

--Initiate action to assure that germplasm in the United States is stored adequately. This should include contacting all curators--both Federal and non-Federal--who store germplasm and determining whether or not they store the germplasm under adequate temperature and humidity controls and are using moisture-resistant containers. Those Federal curators who do not have adequate storage facilities should be required to improve their facilities to meet minimal acceptable conditions or move a sufficient amount of germplasm to storage facilities that can protect germplasm viability. Non-Federal curators should be encouraged to take similar action.

--Initiate projects to implement backup storage. This should include identifying all curators and their germplasm and comparing those results with the germplasm stored at NSSL. USDA should require Federal curators to provide germplasm for backup storage to NSSL and require NSSL to assure that its germplasm is also being stored with other curators. It should encourage similar action for non-Federal curators.

--Take an accurate inventory of the small grains collection. This should include a physical comparison of germplasm in storage and on inventory records, taking appropriate actions to acquire missing germplasm.

--Verify the need for germination testing equipment at all curator storage facilities. Because some of the curators do not work for USDA, the agency cannot require corrective actions by all curators. If such equipment is not available at non-Federal locations, USDA should encourage the curators to obtain the equipment. If monitoring equipment is not to be obtained, USDA should encourage the curator to move some of the seed--enough to ensure its continued preservation--to a storage facility with germination testing equipment or arrange for periodic testing at a testing facility.

--Determine the extent curators are behind in their germplasm grow-out programs. Following this assessment, needs should be ranked so that available assistance can be provided to assure that germplasm most in danger of losing its viability is preserved.

A representative of the Cooperative State Research Service believed that our recommendations should have included the need for increased attention for long-term germplasm storage research especially for the effects of cryogenics (germplasm stored at extremely cold temperatures) on seed longevity. Our review did not address the need for such research.

AGENCY COMMENTS

USDA generally agreed with our conclusions and recommendations. The ARS Administrator believed that our recommendations are consistent with those developed by USDA's germplasm task force. (See p. 5.) He said that these recommendations would be used to help develop the fiscal year 1984 germplasm budget.

USDA provided technical comments or had some relatively minor areas of concern with sections of this report. We made adjustments where necessary. These changes did not affect our conclusions or recommendations.

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